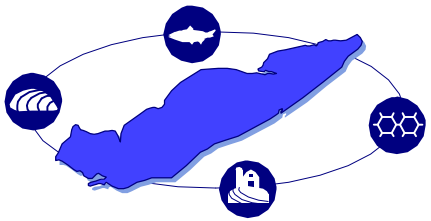


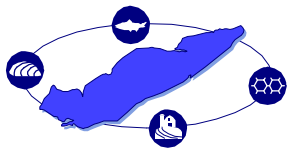
Modeling And Multiobjective Risk Decision Tools for Ecosystem Management

Benjamin F. Hobbs[1]
Richard Anderson[2]
Jong Bum Kim[1]
Joseph F. Koonce[3]

1. Dept. of Geography & Environmental Engineering, The Johns Hopkins University
2. National Oceanic & Atmospheric Administration
3. Dept. of Biology,Case Western Reserve University

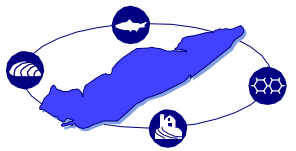
Goal of Presentation

- Demonstrate how ecosystem-based fisheries management can be joined with ecological risk analysis under multiple management objectives



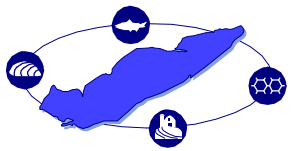
Goal of Presentation

- Demonstrate how ecosystem-based fisheries management can be joined with ecological risk analysis under multiple management objectives
- Introduce tools:
  - Ecosystem model
  - Multiobjective tradeoff analysis
  - Bayesian evaluation of ecological research



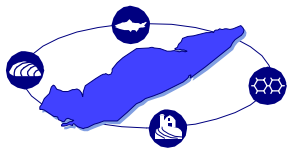
I. Unresolved Problems in Lake Erie

- Major decline of fisheries in 1990s
- Unknown effects of exotic species
  - Zebra Mussel invasion since 1988
  - Round Goby increase in 1990s
  - Expected invasion of Ruffe



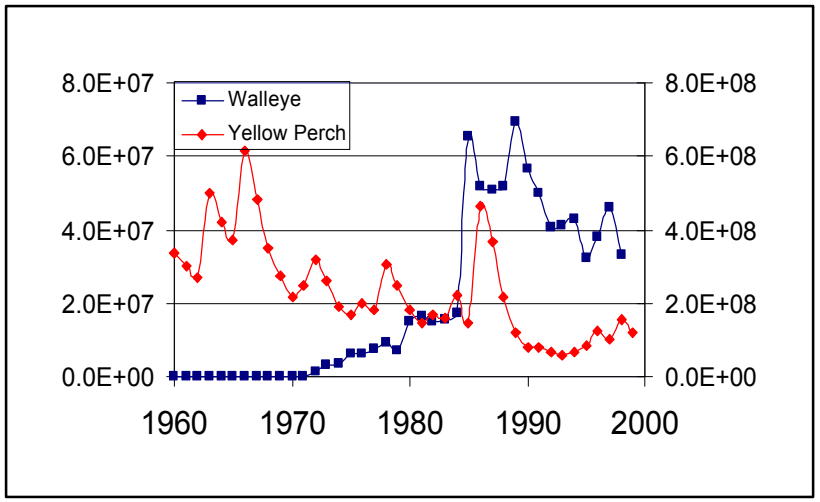
I. Unresolved Problems in Lake Erie

- Major decline of fisheries in 1990s
- Unknown effects of exotic species
  - Zebra Mussel invasion since 1988
  - Round Goby increase in 1990s
  - Expected invasion of Ruffe
- Declining productivity caused by decrease in P loading
- Uncertain role of habitat



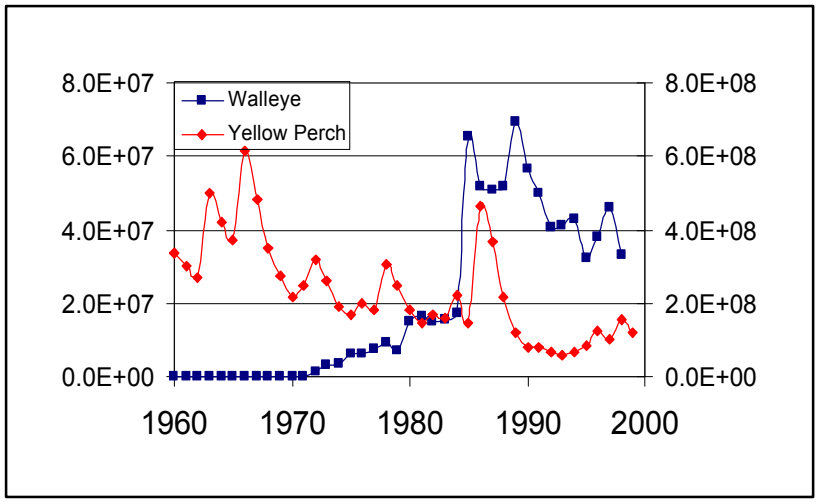
Historical Variation in Fish Harvest and Environment in Lake Erie

Harvest Trends

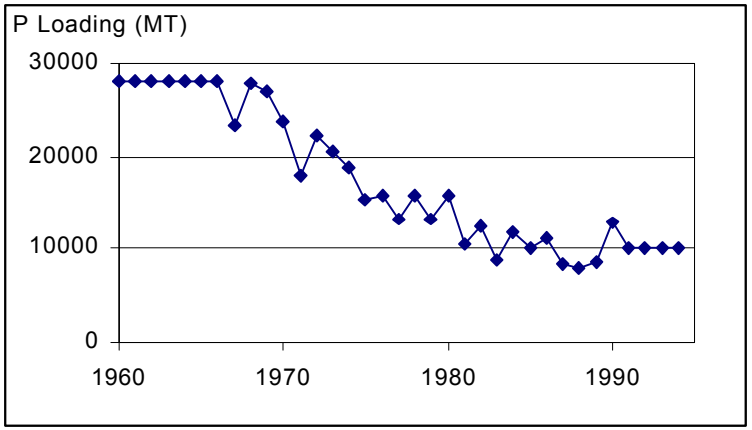


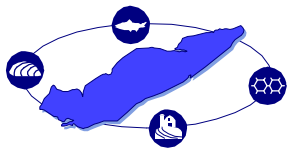
Historical Variation in Fish Harvest and Environment in Lake Erie

Harvest Trends

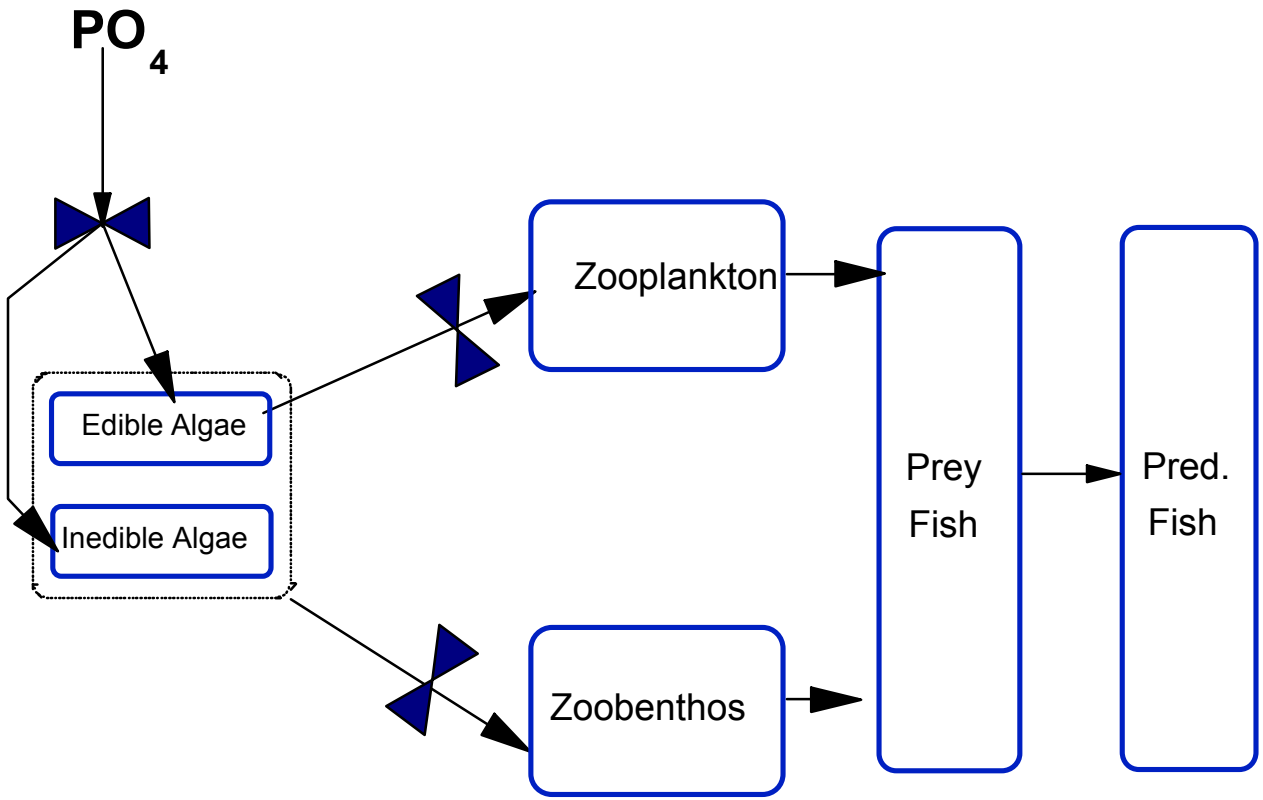


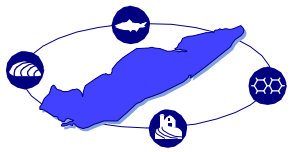
Phosphorus Loading



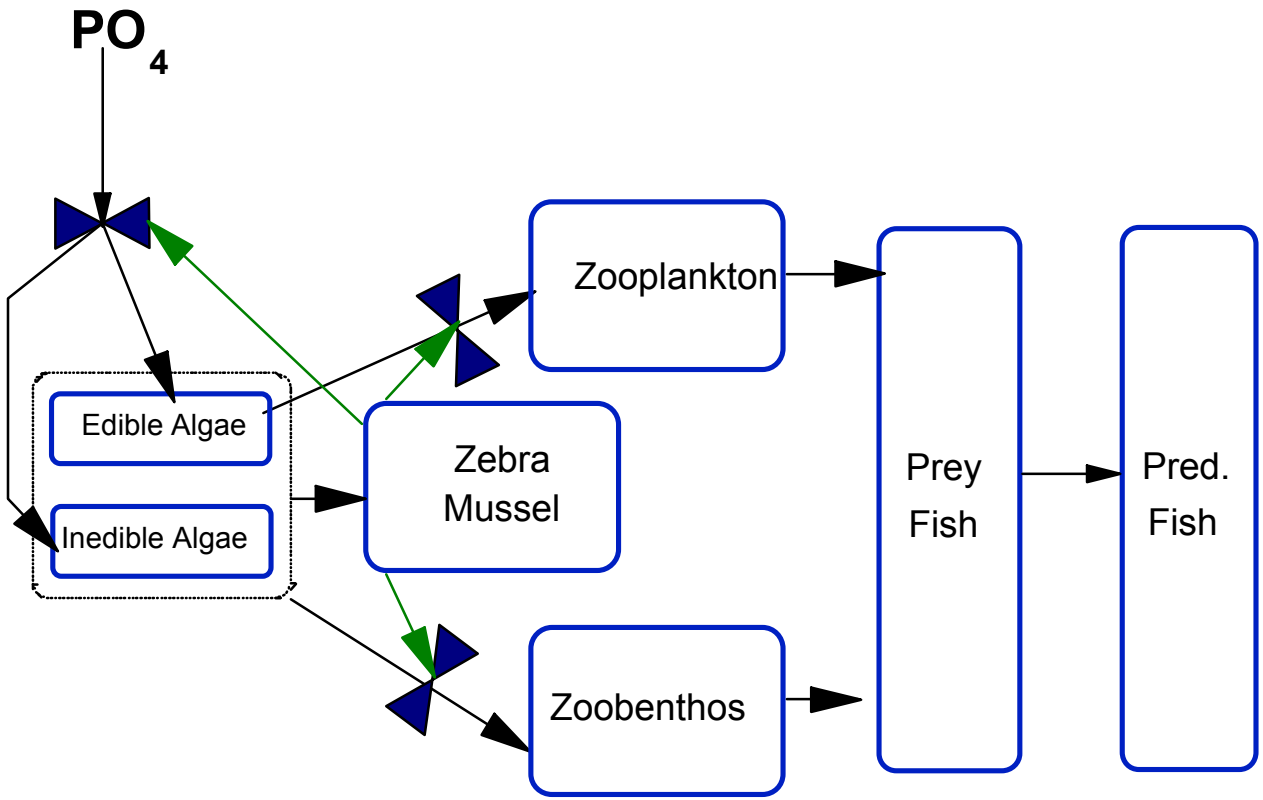


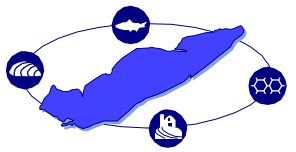
II. Modeling Tradeoffs among Productivity, Exotics, & Fisheries: Lake Erie Ecological Model (LEEM)



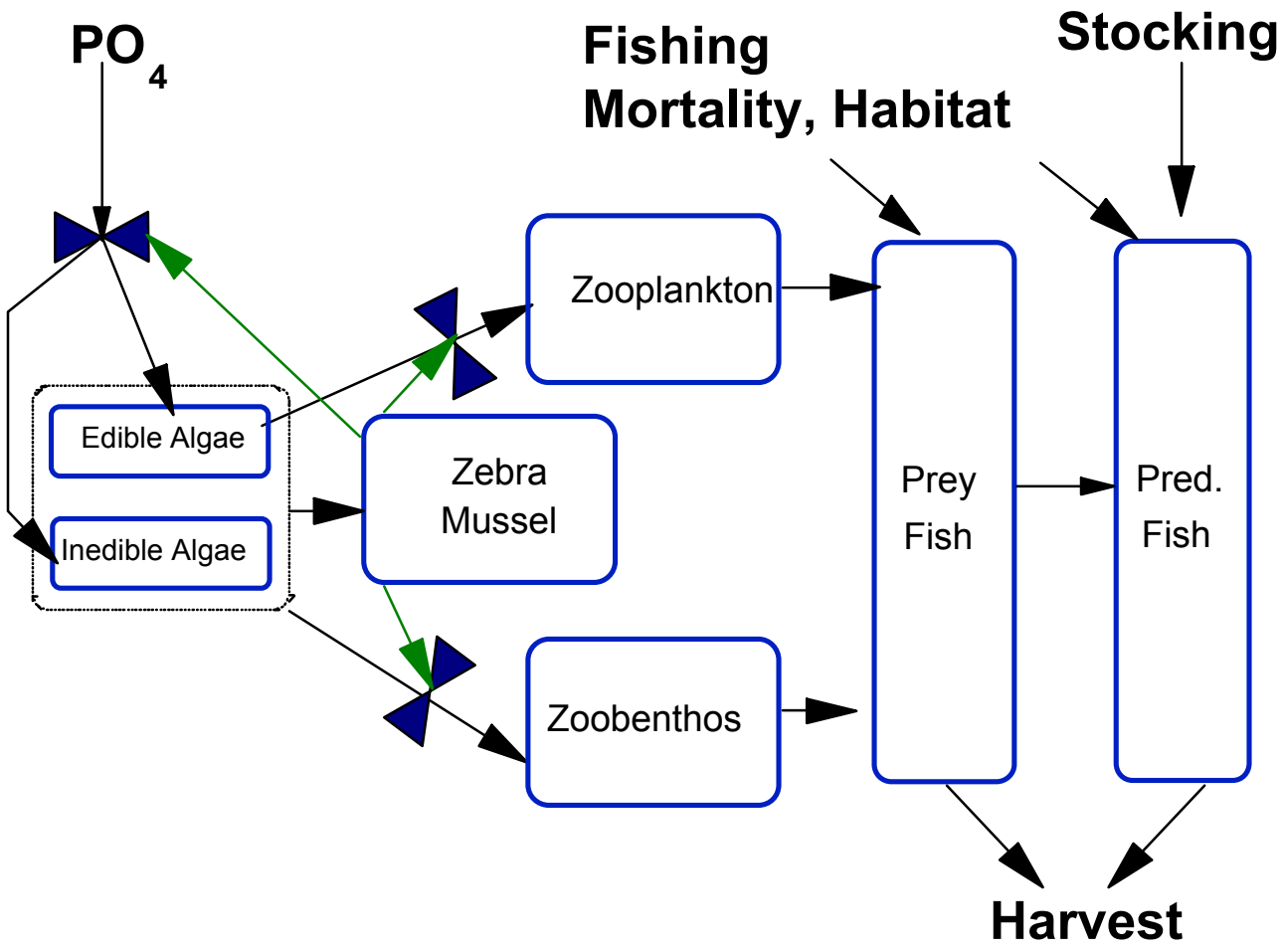


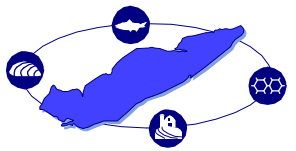
II. Modeling Tradeoffs among Productivity, Exotics, & Fisheries: Lake Erie Ecological Model (LEEM)



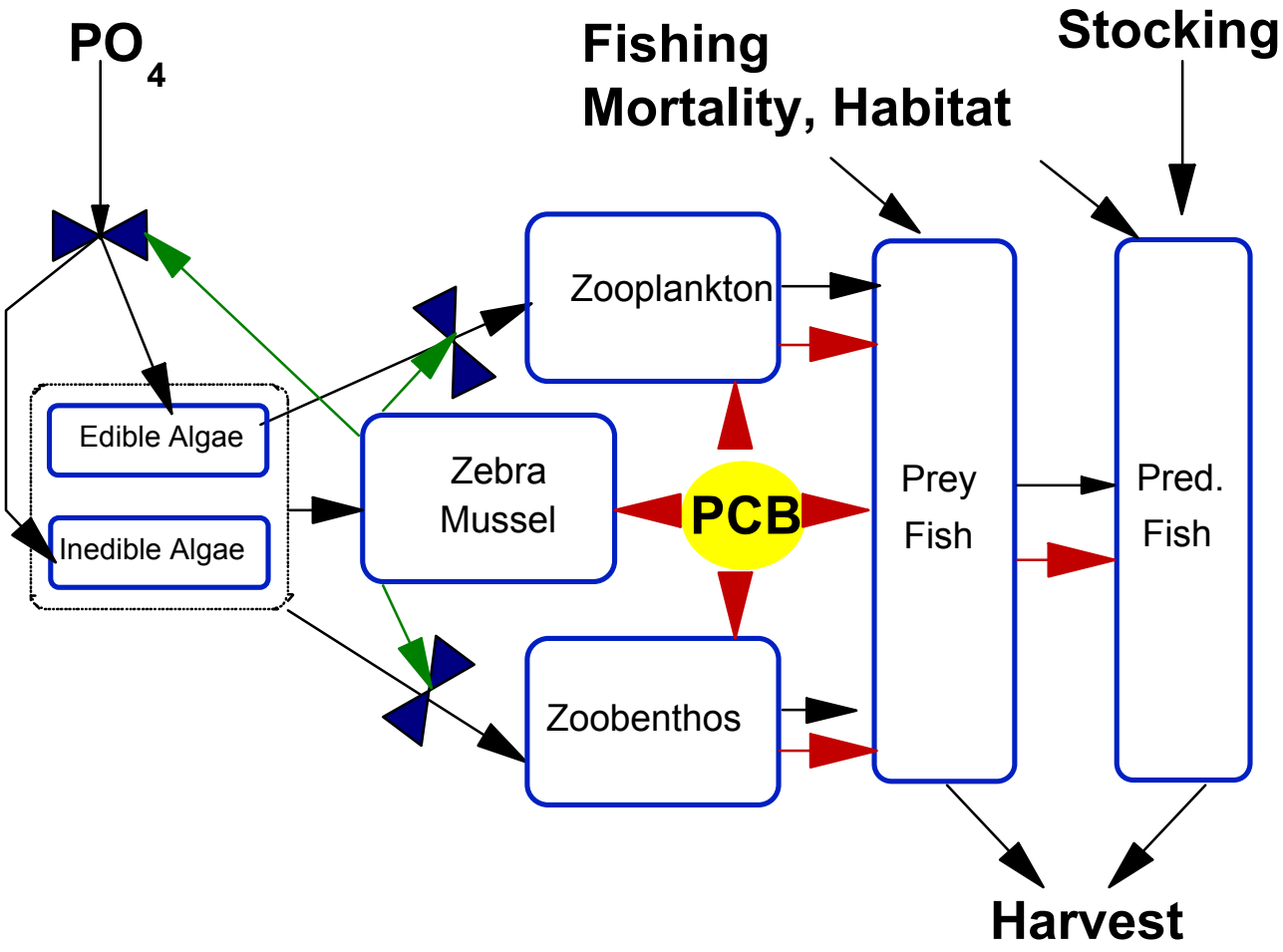


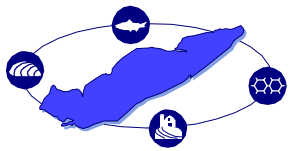
II. Modeling Tradeoffs among Productivity, Exotics, & Fisheries: Lake Erie Ecological Model (LEEM)





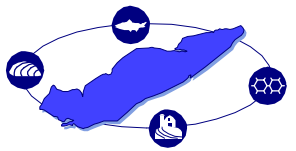
II. Modeling Tradeoffs among Productivity, Exotics, & Fisheries: Lake Erie Ecological Model (LEEM)





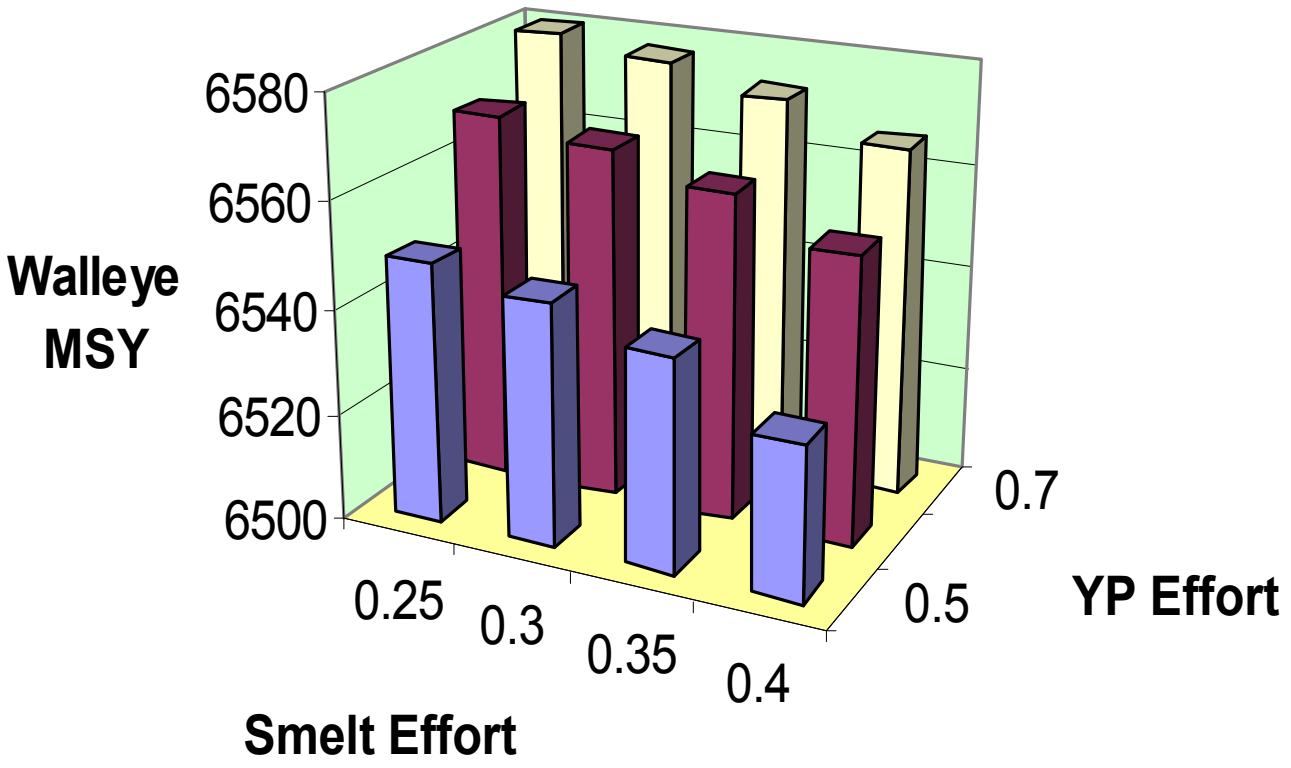
The Need for Multispecies Management: Effects of Species Interactions on Max Sustained Yield

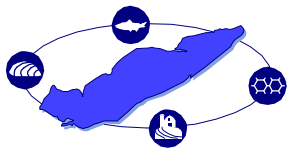
- Optimal exploitation of predator varies with fishing rates of prey species



The Need for Multispecies Management: Effects of Species Interactions on Max Sustained Yield

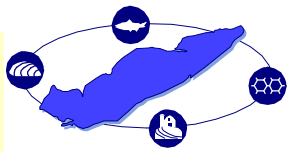
- **Optimal exploitation of predator varies with fishing rates of prey species**



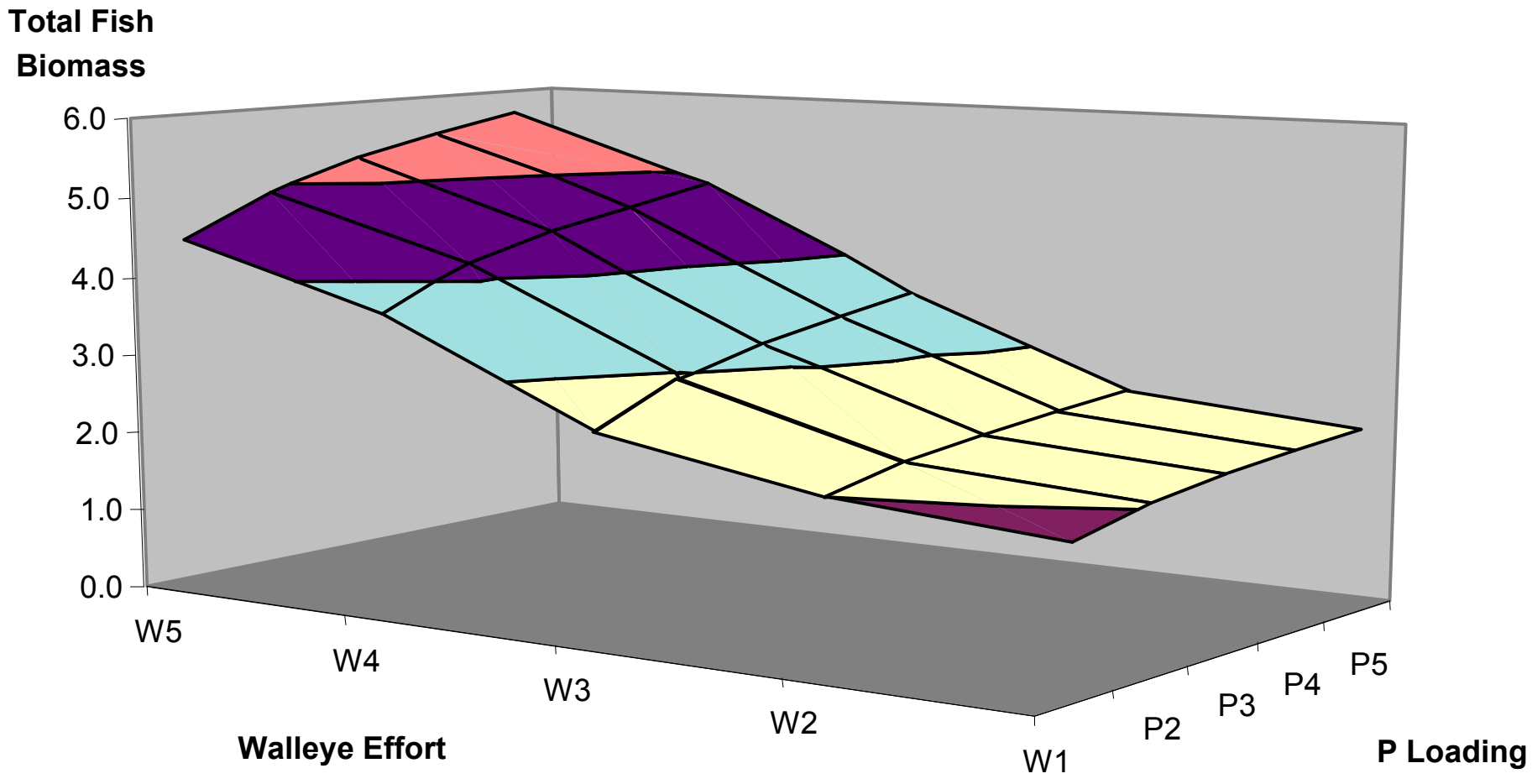


Interaction of Walleye Harvest & Phosphorus Loading

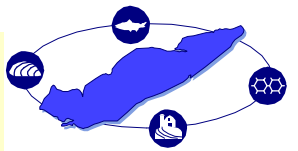
Walleye abundance/harvest has a greater influence on total fish biomass than P loading



Interaction of Walleye Harvest & Phosphorus Loading

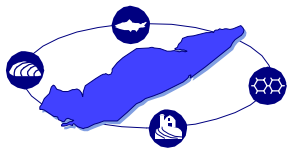


Walleye abundance/harvest has a greater influence on total fish biomass than P loading



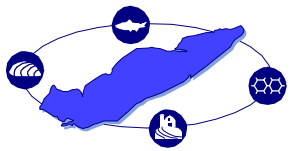
Implications of LEEM Studies

- **Fisheries and P Loading Jointly Determine Optimal Exploitation of Species**



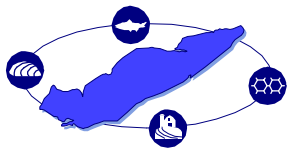
Implications of LEEM Studies

- Fisheries and P Loading Jointly Determine Optimal Exploitation of Species
- Derivation of Quotas for Single Species without Considering Interactions Can Lead to Overexploitation
  - Prey and predators cannot be managed independently



III. Value of Research: Multiobjective Bayesian Framework

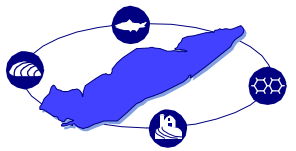
- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**



III. Value of Research: Multiobjective Bayesian Framework

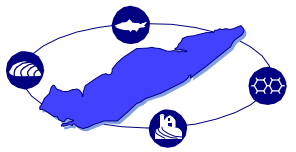
- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**
- **Necessary elements:**

  1. ***Management context:*** **Alternatives, objectives, decision rule**



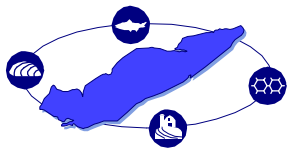
III. Value of Research: Multiobjective Bayesian Framework

- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**
- **Necessary elements:**
  1. ***Management context:*** **Alternatives, objectives, decision rule**
  2. ***What we know now:*** **"States of nature" (hypotheses, parameter distributions), and confidence in each ("prior probabilities")**



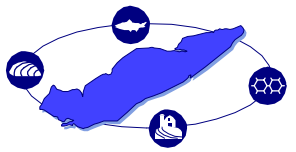
III. Value of Research: Multiobjective Bayesian Framework

- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**
- **Necessary elements:**
  1. ***Management context:*** **Alternatives, objectives, decision rule**
  2. ***What we know now:*** **"States of nature" (hypotheses, parameter distributions), and confidence in each ("prior probabilities")**
  3. ***Research:*** **Information options (monitoring, modeling, experiments), and what might be learned**



III. Value of Research: Multiobjective Bayesian Framework

- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**
- **Necessary elements:**
  1. ***Management context:*** **Alternatives, objectives, decision rule**
  2. ***What we know now:*** **"States of nature" (hypotheses, parameter distributions), and confidence in each ("prior probabilities")**
  3. ***Research:*** **Information options (monitoring, modeling, experiments), and what might be learned**
  4. ***System response:*** **LEEM, expert judgment**



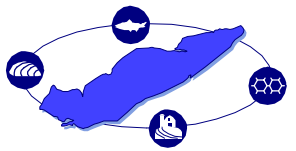
III. Value of Research: Multiobjective Bayesian Framework

- **Information has value *only* if it can change decisions and improve outcomes**
  - **"Value" is multidimensional!**
- **Necessary elements:**
  1. ***Management context:*** **Alternatives, objectives, decision rule**
  2. ***What we know now:*** **"States of nature" (hypotheses, parameter distributions), and confidence in each ("prior probabilities")**
  3. ***Research:*** **Information options (monitoring, modeling, experiments), and what might be learned**
  4. ***System response:*** **LEEM, expert judgment**
  5. ***Integrating framework:*** **A way of determining how information affects our knowledge and choices: *Decision trees, Bayes' rule***

Problem Structure

Two decision stages

- Research project; e_h
- P loading and fisheries management; $\underline{a}_s = \{a_{s1}, a_{s2}, a_{s3}, a_{s4}\}$



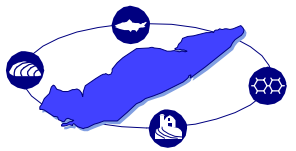
Problem Structure

Two decision stages

- Research project; e_h
- P loading and fisheries
- management; $\underline{a}_s = \{a_{s1}, a_{s2}, a_{s3}, a_{s4}\}$

Uncertainties ?

- Lower trophic level;
- Other uncertainties;



Problem Structure

Two decision stages

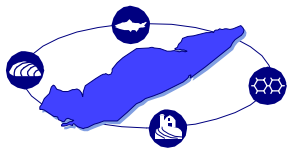
- Research project; e_h
- P loading and fisheries management; $\underline{a}_s = \{a_{s1}, a_{s2}, a_{s3}, a_{s4}\}$

Uncertainties ?

- Lower trophic level;
- Other uncertainties;

Outcomes

- 10 Attributes $\underline{X}$, combined using additive utility function $U(\underline{X})$

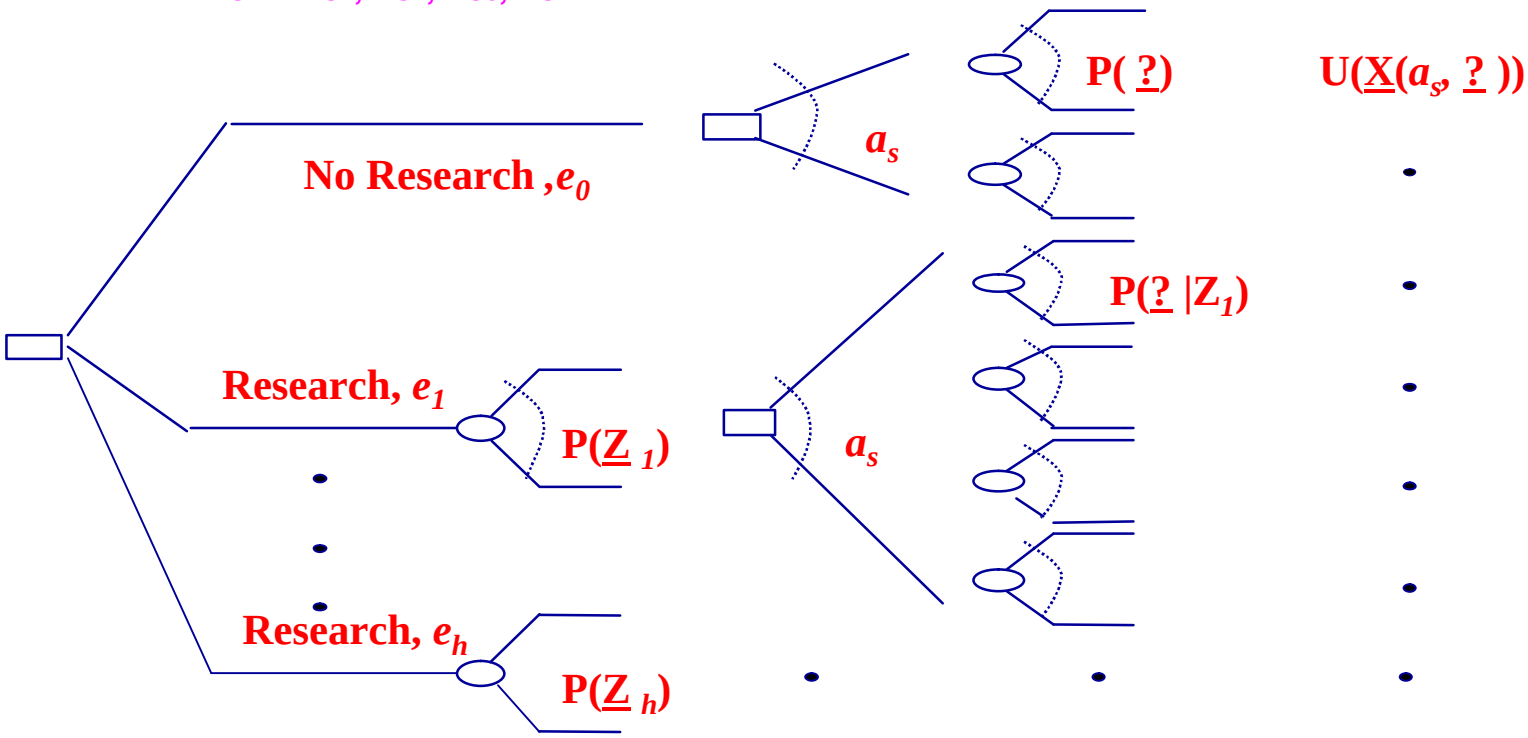


Problem Structure

Two decision stages
- Research project; e_h
- P loading and fisheries management; $\underline{a}_s = \{a_{s1}, a_{s2}, a_{s3}, a_{s4}\}$

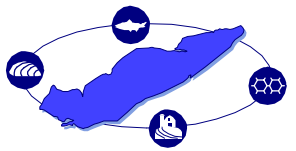
Uncertainties ?
- Lower trophic level;
- Other uncertainties;

Outcomes
- 10 Attributes $\underline{X}$, combined using additive utility function $U(\underline{X})$



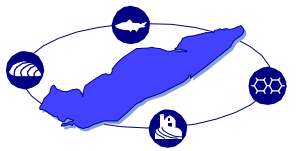
Management Levers

- **Phosphorus Loads:**
  - **5K, 10K (as is), and 15K ton/yr**



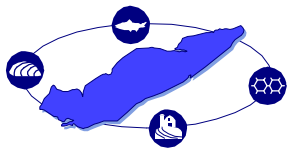
Management Levers

- **Phosphorus Loads:**
  - 5K, 10K (as is), and 15K ton/yr
- **Exploitation effort: A measure of the number of boats or the time they spend fishing**
  - Exploitation: Trawl, Gill Nets, and Sport Harvest
  - Base = historical exploitation level
  - Vary exploitation by ± 50%



Present State of Knowledge

- **Prior probabilities**
  - **Uncertainties in LEEM parameters**



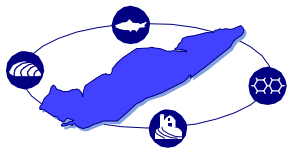
Present State of Knowledge

- **Prior probabilities**
  - Uncertainties in LEEM parameters
  - Hypotheses presented at 1999 IAGLR Modeling Summit and Lake Erie Millenium Conference
    - **Changes in structure of lower trophic level**

      (e.g., Zoobenthos production efficiency)
    - **The role of zebra mussels in Lake Erie energy and nutrient flows**

      (e.g., Zebra mussel recycling nutrients;

      Primary productivity as function of P loading)



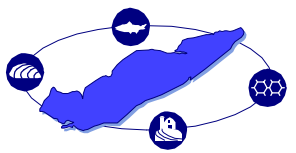
Present State of Knowledge

- **Prior probabilities**
  - Uncertainties in LEEM parameters
  - Hypotheses presented at 1999 IAGLR Modeling Summit and Lake Erie Millenium Conference
    - Changes in structure of lower trophic level

      (e.g., Zoobenthos production efficiency)
    - The role of zebra mussels in Lake Erie energy and nutrient flows

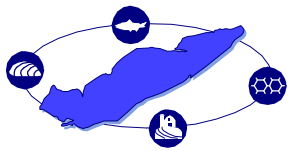
      (e.g., Zebra mussel recycling nutrients;

      Primary productivity as function of P loading)
- **Disregarding uncertainties may result in inappropriate, nonrobust decisions**



Options for Gathering Information

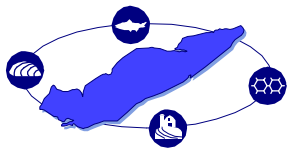
- **Characteristics of research**
  - Cost & time
  - Reliability of outcomes



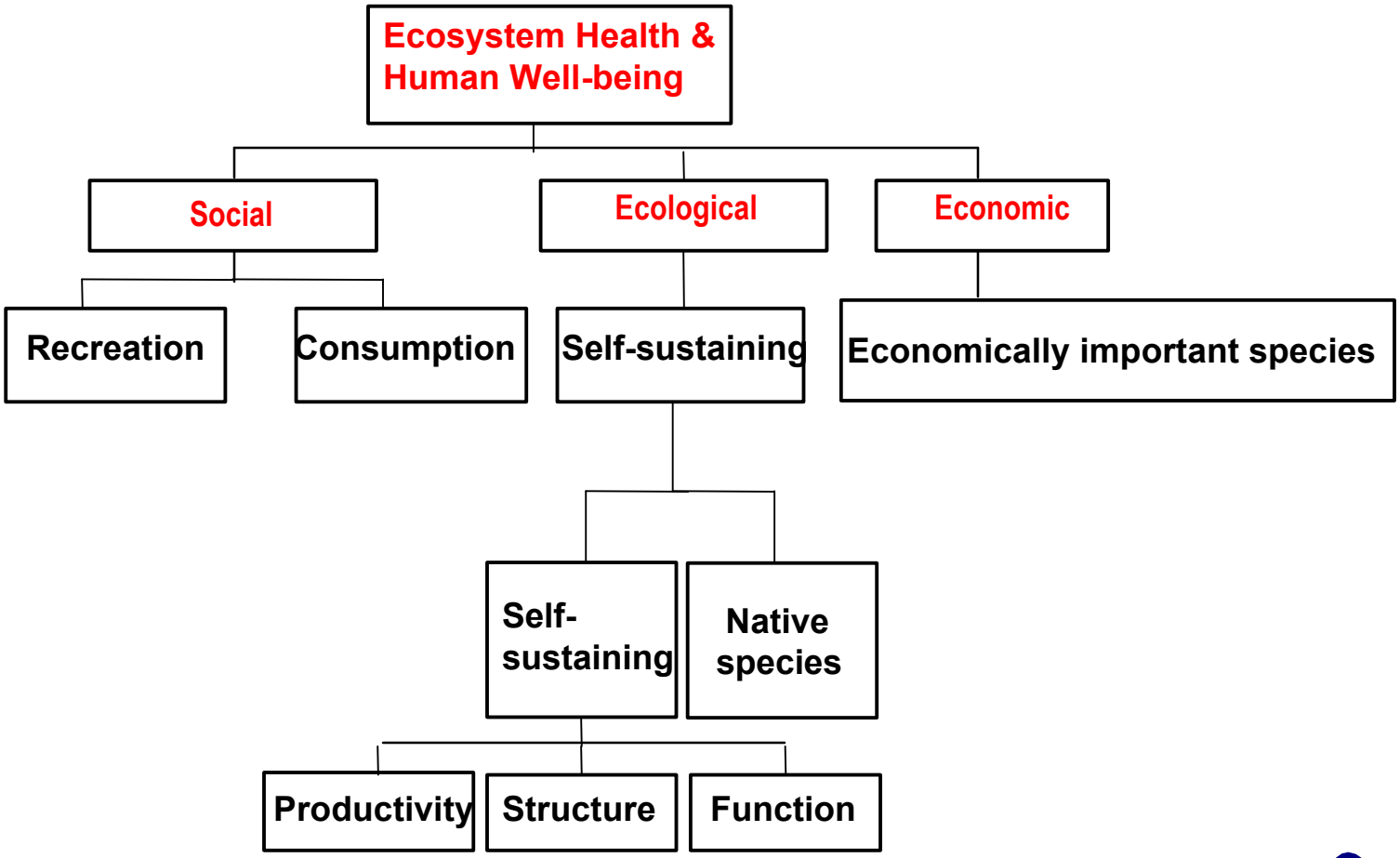
Options for Gathering Information

- **Characteristics of research**
  - Cost & time
  - Reliability of outcomes

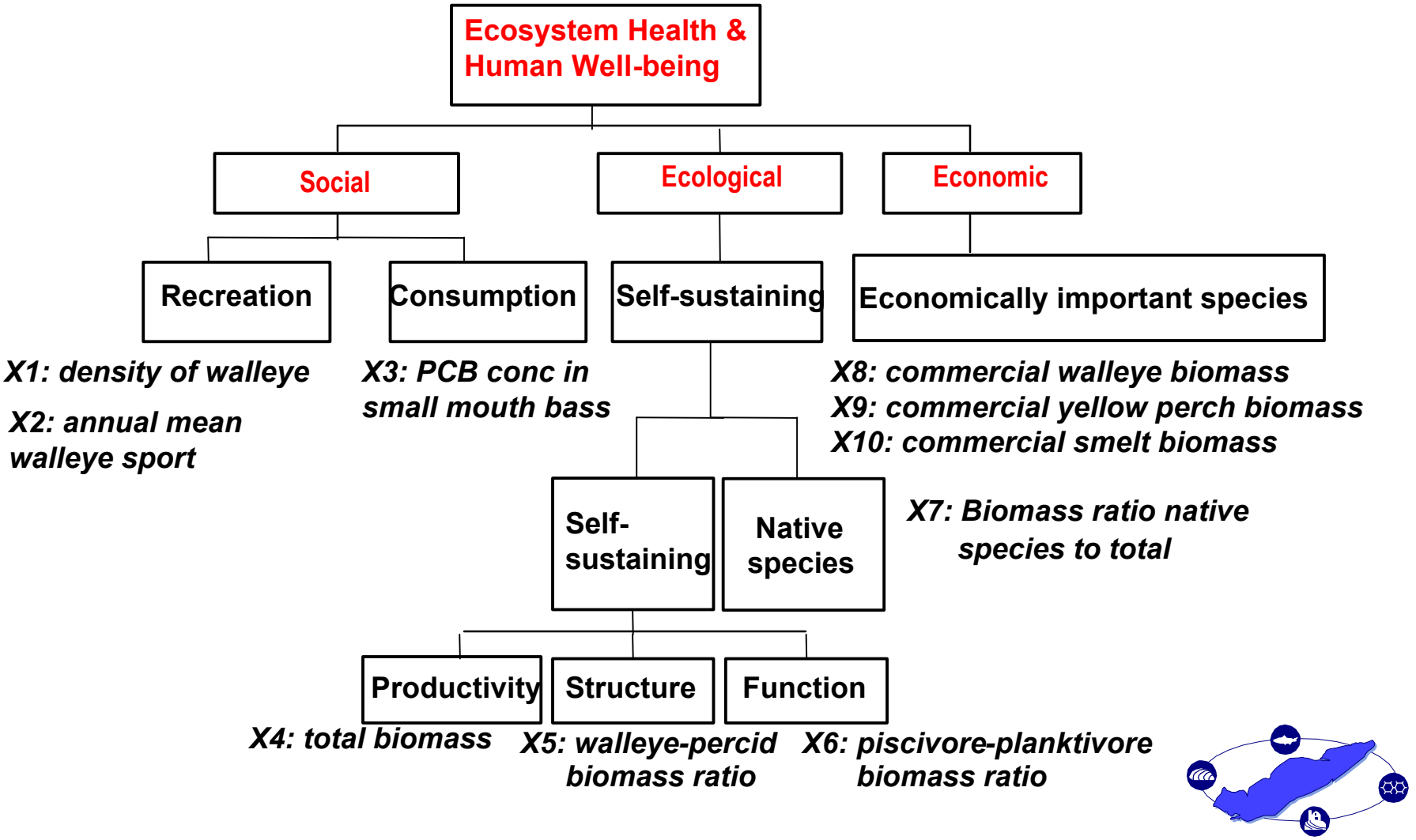
- **Estimating the value of research**
  - Research revises prior probabilities ➪ "Posterior probabilities" (new state of knowledge)
  - New knowledge may influence management decisions
  - Calculate value by simulating decisions *with* and *without* new information



Multiple Objective Framework for Risk Analysis

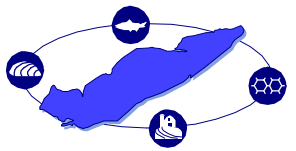


Multiple Objective Framework for Risk Analysis



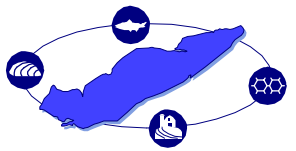
Bayesian Analysis Results

- **Priorities for objectives can affect decisions**
  - **All participants prefer *High* trawling; most *High* sport harvest**
  - ***Split* on Gill net effort**



Bayesian Analysis Results

- **Priorities for objectives can affect decisions**
  - All participants prefer *High* trawling; most *High* sport harvest
  - *Split* on Gill net effort
- **Ignoring uncertainty can change decisions**
  - True for 2 of 6 participants
  - Uncertainty about *Zoobenthos productivity effects of zebra mussels* most important (perfect information changes decisions)
  - Uncertainties about *Zooplankton productivity* and *Zebra mussel recycling* also important

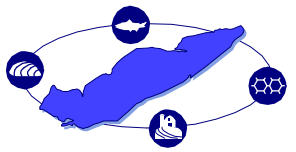


Bayesian Analysis Results

- **Priorities for objectives can affect decisions**
  - All participants prefer *High* trawling; most *High* sport harvest
  - *Split* on Gill net effort
- **Ignoring uncertainty can change decisions**
  - True for 2 of 6 participants
  - Uncertainty about *Zoobenthos productivity effects of zebra mussels* most important (perfect information changes decisions)
  - Uncertainties about *Zooplankton productivity* and *Zebra mussel recycling* also important
- **The value of research stems (in part) from its effect on decisions. Research has value for 5 of 6 participants**
  - Two projects most valuable:
    - ➲ Goby predation on mussels
    - ➲ Lakewide estimates of productivity
  - Worth: 10^1 - 10^4 tons/yr equivalent of Walleye sport harvest

Summary

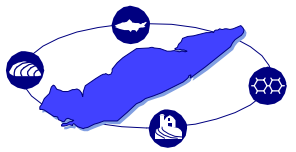
- **Heuristic application of LEEM can lead to multi-fishery rules that recognize uncertainties (P, invasions, habitat)**



Summary

- **Heuristic application of LEEM can lead to multi-fishery rules that recognize uncertainties (P, invasions, habitat)**
- **“Ecosystem Health” can be operationalized**

  E.g., Lake Erie stakeholders compared alternative futures using fuzzy cognitive maps and multiobjective analysis. Value judgments combined diverse “health” attributes, such as productivity, aesthetics, & community structure.



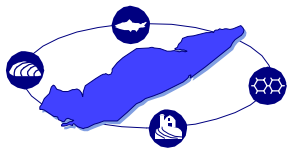
Summary

- **Heuristic application of LEEM can lead to multi-fishery rules that recognize uncertainties (P, invasions, habitat)**
- **"Ecosystem Health" can be operationalized**

  E.g., Lake Erie stakeholders compared alternative futures using fuzzy cognitive maps and multiobjective analysis. Value judgments combined diverse "health" attributes, such as productivity, aesthetics, & community structure.

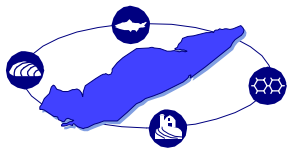
- **Multiobjective Bayesian analysis can include ecological uncertainties in management, and quantify the value of research**

  E.g., fish managers made value and probability judgments for a risk analysis, & showed that intensive monitoring of lower trophic level productivity could improve fisheries management



Take Home Message:

- Methods to model the decision-making process itself (multiobjective tradeoff analysis, decision trees, Bayesian risk analysis) provide an important complement to science intended to develop indicators of ecosystem health
- Could be applied to MAIA or any region to support ecosystem management



Acknowledgments

- Research support provided by the International Joint Commission and US Environmental Protection Agency (STAR R82-5150)
- US and Canadian environmental & natural resources managers and stakeholders for participating in modeling workshops and providing data and guidance in model development